The Effect of Timing of the Final Seasonal Nitrogen Fertigation on Early Fruit Maturity, Fruit Diameter, and Leaf Nitrogen on Navel Oranges

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ADDITIONAL INDEX WORDS. *Citrus sinensis*, nitrogen fertilization, soluble solids concentration, titratable acidity, fruit color, fruit size

SUMMARY. Previous research has shown that nitrogen fertilization rates may influence fruit quality characteristics of navel oranges [*Citrus sinensis* (L.) Osbeck]. The objective of this study was to determine, for equal seasonal N applications, if the timing of the last seasonal nitrogen fertigation promotes early fruit maturity or affects fruit size. The study consisted of four treatments with the total seasonal allocation of nitrogen fertilizer applied by $\approx$ 1 May, 1 June, 1 July, and 1 Aug. in an experimental site in a commercial orange grove in the southern San Joaquin Valley of California. The source of nitrogen was a liquid calcium ammonium nitrate injected through the irrigation system. No significant treatment differences in soluble solids concentration, titratable acidity, the ratio of soluble solids concentration to titratable acidity, percent juice, fruit color and fruit diameter were detected in fruit

sampled in October. Similarly, in September, no significant differences in leaf nitrogen were found among treatments. These results do not support the hypothesis that applying the total seasonal application of nitrogen early in the season results in earlier orange maturity or larger fruit size, at least not for trees that have leaf N in the optimum range.

The San Joaquin Valley of California has $\approx$ 210,000 acres (85,000 ha) of citrus, most of which are navel oranges. To ensure quality, the oranges must meet minimum legal standards of sweetness and color before they can be marketed. Orange growers receive a price premium in the marketplace for producing early navels. How nitrogen (N) might be managed to promote an earlier development of color and an acceptable solids/acid ratio is a question of interest to the grower.

Previous research has shown that leaf N is indicative of the N status of mature citrus trees (Chapman, 1968). Total N of 2.4% to 2.6% of leaf dry weight is generally considered optimum to provide adequate yield, fruit size and quality. Generally, high concentrations of leaf N are associated with higher yields, higher fruit numbers, delayed color break, lower solids/acid ratios, and smaller fruit size (Embleton et al., 1978). Thus the grower must balance applying enough N to the tree for adequate yield, tree health, and vigor, with no adverse effects on fruit size and quality.

Most oranges in the southern San Joaquin Valley are irrigated with low-volume irrigation and the principal method of applying N is by fertigation. There exists an undocumented belief among some growers that fertigating later in the season will provide pulses of readily available N to the maturing fruit, encouraging luxury consumption leading to adverse affects on fruit quality and color break. Some growers attempt to minimize this undocumented effect by applying the total seasonal N allocation by May or early June so the N might be more available during flowering, fruit set, and the early and mid stages of fruit growth with a slow but uniform decline in availability as the fruit progresses toward maturity. Information in the scientific literature on the effect of timing of N fertilization on navel orange yield

and fruit quality is mixed (Embleton et al., 1973).

The objective of this study was to determine, for equal seasonal N applications, if the final N application date affects fruit maturity and fruit size.

Materials and methods

EXPERIMENTAL SITE. The study was conducted in a commercial orange grove planted adjacent to the foothills in the southeastern corner of the San Joaquin Valley of California near the city of Arvin. The Hesperia sandy loam soil is very deep, and gently sloping (Valverde and Hill, 1981). In this area, full bloom normally occurs in early April and the fruit are typically picked in November before an orange peel color develops. 'Fisher' navel orange [*Citrus sinensis* (L.) Osbeck] on 'Carrizo' rootstock [*Citrus sinensis* (L.) Osbeck $\times$ *Poncirus trifoliata* (L.) Raf.] were planted in 1985 with a 22 ft (6.7 m) between row and 19 ft (5.8 m) between tree spacing. Each tree was irrigated using five 1-gal/h ($3.8\text{-L}\cdot\text{h}^{-1}$) drip emitters spaced at equal intervals along the single hose irrigating each row of trees. The water infiltration rate after an irrigation was such that the leading edge of the wetted pattern on the soil surface remained within 3 ft (0.9 m) of either side of the irrigation hose.

NITROGEN TREATMENTS. A treatment was identified by the date at which the final N fertilizer for the season was applied to each experimental unit. Each treatment received equal quantities of N fertilizer during the season. Final N application dates were 2 May, 31 May, 2 July, and 2 Aug. 1996 and 1 May, 2 June, 1 July, and 1 Aug. 1997. For identification purposes, the treatments are designated as May, June, July, and August and each plot received two, three, four and five fertigations, respectively. The N applied per fertigation was reduced accordingly in the plots receiving more frequent fertigation (Table 1).

EXPERIMENTAL DESIGN. The experimental site was established within an area 24 tree rows long by 8 trees wide within a larger grove of citrus. Each treatment was applied to an experimental unit which consisted of the last eight trees at the end of a single row of trees. The experiment was designed as a randomized complete block providing six replications of each of the four treatments. Specifically, the

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Table 1. Timing of last N applications, number of fertigations, and N application rates, Kern County, Calif., 1996–97.

Application date	N applied (lb/acre)			
	Month of last N application			
	May	June	July	August
1996				
11 Mar. 1996	32.2	32.2	32.2	32.2
2 May 1996	86.9	43.5	28.7	21.7
31 May 1996	0.0	43.5	28.7	21.7
2 July 1996	0.0	0.0	28.7	21.7
2 Aug. 1996	0.0	0.0	0.0	21.7
Season total	119.1	119.2	118.3	119.0
1997				
6 Mar. 1997	35.8	24.0	18.0	14.0
1 May 1997	49.2	32.8	24.6	20.6
1 June 1997	0.0	28.2	21.5	17.4
1 July 1997	0.0	0.0	20.7	16.6
1 Aug. 1997	0.0	0.0	0.0	16.4
Season total	85.0	85.0	84.8	85.0

experiment was divided into three blocks. Each block contained two replications of each of the four treatments, with all treatments completely randomized within a block. Fruit size and quality data were analyzed using ANOVA (Manugistics, 1997).

Valves were installed in the irrigation line of each experimental unit so that it could be fertigated independently of the rest of the grove. Nitrogen, in the form of liquid calcium ammonium nitrate 17% N (11.6% as nitrate N, 5.4% as ammonium N) and 8.8% calcium by weight, was diluted with water (1:3 ratio) and was applied by injection to each experimental unit through the end of the irrigation line servicing each row of trees. 119 lb/acre (133 kg·ha⁻¹) of N was applied in 1996 and 85 lb/acre (95 kg·ha⁻¹) in 1997.

FRUIT QUALITY AND LEAF N MEASUREMENTS. Fruit was sampled when approximately 75% of the fruit in the grove began changing color. Ten fruit were sampled at random from the four

trees in the center of the experimental unit, avoiding sunburned and scarred fruit. Percent soluble solids concentration (SSC) and percent titratable acidity in citric acid equivalents (TA) were measured by the method of Ting and Ruseff (1986). The SSC and TA measurements were made by Paramount Farming's mobile laboratory in the grove on 22 Oct. 1996 from fruit picked the same day. Fruit harvested on 16 Oct. 1997 were analyzed at the F. Gordon Mitchell Postharvest Laboratory at the Kearney Agricultural Center near Parlier, Calif., on 16 Oct. Furthermore, on 17 Oct., 1997, percent juice was calculated based on the ratio of juice weight to fruit weight and peel color was determined through the use of a chromameter (model CR-300 with a model DP-301 data processor unit, Minolta) and using the Commission Internationale De l'Eclairage L*C*H system of measurements, (McGuire, 1992). Two nondestructive color measurements were taken on opposite sides of each orange.

On 17 Oct. each year, fruit diam-

eter was measured in the grove using an electronic caliper on a random sampling of fruit 4 to 5 ft (1.2 to 1.8 m) from the ground around the periphery of the three most uniform of the four trees in the center of each experimental unit. In 1996, 32 fruit per plots were measured and, in 1997, 75 were measured.

Nonterminal leaves from the spring flush of growth were collected on 6 Sept. 1996 and 12 Sept. 1997, at random from nonfruiting branches around the periphery of the four most centrally located trees in the experimental unit. These leaf tissue samples were washed in distilled water, dried in a forced-air oven for 72 h at 70 °C. Total N was determined by a nitrogen gas analyzer using induction furnace and thermal conductivity (Sweeney, 1989) at the University of California, Dept. of Agricultural and Natural Resources Analytical Laboratory, Davis.

Results and discussion

Approximately equal quantities of N were applied to each of the four treatments each season (Table 1) and leaf N values were not significantly different among N termination dates (Table 2). Fruit diameter or other fruit quality characteristics differed between 1996 and 1997 probably as a function of weather, yet there were no significant differences among treatments within a given year (Table 2).

The leaf N concentration was similar for treatments in 1996 and 1997 despite the difference in number of fertigations and the variable length of time between the last N fertigation and the September leaf sampling date. The N that was applied early in the season in the May and June treatments appears to have remained available to the oranges through the season based on the similar September leaf N con-

Table 2. Fruit quality characteristics, diameter, and leaf N, Kern County, Calif., 1996–97

Treatment	Fruit quality characteristics (n = 10)														
Last	SSC ^z		TA ^y		SSC/TA			Color ^x			Juice	Fruit diam ^w		Leaf N	
N	(%)		(%)				L*	C*	H°	(%)	(mm)		(%)		
fertigation	1996	1997	1996	1997	1996	1997	1997	1997	1997	1997	1996	1997	1996	1997	
May	10.1a	9.2 a ^v	0.90a	1.15 a	11.2 a	8.1 a	57.9 a	45.2 a	116.7 a	47.4 a	68 a	73 a	2.5 a	2.6 a	
June	10.0 a	9.2 a	0.90 a	1.21 a	11.0 a	7.7 a	57.0 a	44.4 a	117.3 a	47.7 a	67 a	72 a	2.6 a	2.6 a	
July	10.0 a	9.2 a	0.91 a	1.19 a	11.0 a	7.8 a	57.3 a	44.1 a	117.0 a	47.1 a	68 a	72 a	2.6 a	2.6 a	
August	10.0 a	9.0 a	0.93 a	1.15 a	10.6 a	7.9 a	57.8 a	44.4 a	116.8 a	47.3 a	67 a	72 a	2.5 a	2.7 a	

^zSoluble solids concentration.

^yTitratable acidity in citric acid equivalents.

^xL* = intensity, C* = chroma, H° = hue in degrees (CIE units).

^wn = 32 in 1996 and 75 in 1997.

^vData analyzed using ANOVA. Mean separation within columns by LSD at *P* = 0.05.

centrations among treatments. This stability suggests that N leaching through the soil profile was not a significant problem even on this sandy soil and that the grower managed irrigation water effectively. That the leaf N concentration remained at $\approx 2.6\%$ and did not go higher, also suggests that residual soil N from previous seasons was not an important factor since leaf N concentrations routinely exceed 3% in groves receiving high rates of fertilizer N.

These results indicate that for adequately fertilized trees applying the total seasonal N allocation early in the season does not result in a higher SSC/TA ratio, earlier color break or larger fruit diameter. Growers that apply the total seasonal N application early in the season should not expect earlier fruit maturity. However, research has demonstrated that N utilization and metabolism increases during bloom and fruit set (Kato, 1986) and applying most of the N during this period from April to June in the San Joaquin Valley has been a recommended practice.

Previous work by Embleton et al. (1978) suggests that a leaf N concentration below 2.4 might lead to a high SSC/TA ratio earlier in the season. However, the practicality of maintaining constant leaf N concentration using fertilizer management remains problematic since weather, previous and current yield and management practices all combine to produce a given leaf N concentration.

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Muskmelon Transplant Production in Response to Seed Priming

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ADDITIONAL INDEX WORDS. *Cucumis melo*, osmoconditioning, stand establishment

SUMMARY. The effects of seed priming on seedling development of muskmelon (*Cucumis melo* L.) under laboratory and greenhouse conditions were studied. Seeds of 'Top Net, SR' muskmelon were primed for 6 days in darkness at 77 °F (25 °C) in KNO₃ (0.35 M) aerated solution. After germination in petri dishes at 77 °F, primed and nonprimed seeds were transferred to either paper towels (laboratory study) or trays, which were placed in greenhouse conditions. Leaf area and fresh and dry mass of roots and shoots were measured at 15 and 30 days. In germination under laboratory conditions, primed seeds germinated ≈ 16 and 60 hours earlier than nonprimed seeds at 77 °F and 63 °F (17 °C), respectively. Priming caused no beneficial effect on shoot and root development either in laboratory conditions or during transplant production in the greenhouse.

Recently, a trend in the vegetable industry is to grow transplants in containerized cell trays. Muskmelon transplants have been used to improve stands, reduce seed usage (especially with expensive hybrids) and shorten the time from planting to harvest (Dufault, 1986). Generally, the time required for production of marketable muskmelon

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